Summary of the review of a space charge compensation device for the FNAL Booster

Review committee: R. Baartman (TRIUMF), W. Chou (FNAL), S. Holmes (FNAL),
T. Roser (BNL, Chair), F. Schmidt (CERN), T. Wangler (LANL), R. Webber (FNAL)

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A electron beam lens for the FNAL Booster is proposed to compensate space charge effects of the intense proton beam, in particular at injection. In principle, a electron beam that is perfectly matched to the transverse and longitudinal proton beam profile can completely cancel the direct intra-beam space charge forces and therefore reduce beam emittance growth and consequently beam losses.

The FNAL Booster, built in 1970, is scheduled to deliver significantly higher average proton beam currents by about 2003 when new fixed target experiments will come online. It is planned that the increase will be mostly in the average frequency of Booster pulses and only a modest increase in the number of protons per pulse to 5×10^{12} per pulse is planned. To stay within the present radiation limits the beam losses in the Booster will have to be reduced by about a factor of 20.

The main beam losses in the Booster are in a rather typical fashion associated with extraction, transition energy crossing, early acceleration and rf capture. Only the last two are probably caused by space charge, although this can be rather difficult to prove definitively with beam measurements. In light of this situation, one probably should not solely or even in a major part rely on the space charge compensation to reduce beam losses by the required factor of 20.

Other upgrades or areas for study that were suggested by the committee to reduce beam losses in the Booster are:

- increased aperture of the extraction channel,
- modified lattice to split the vertical and horizontal tune by one unit,
- improvements of the transition energy jump system,
- second harmonic rf system to reduce the bunching factor at injection,
- increased rf gap volts and improved beam loading compensation.

The goal to reduce losses by a factor of 20 in an established machine is very ambitious and will need a multitude of improvements.

However the idea of compensating space charge forces with an electron lens is very attractive and should be tested. Presented techniques and calculations are a very good start towards a design of such a device for the FNAL Booster. Before proceeding towards significant hardware R&D, however, detailed tracking simulations should be completed to confirm space charge compensation directly and also allow the investigation of the sensitivity to mismatch between the electron and proton beam profiles and lattice errors. Also, a Booster lattice that includes the effect of both the electron beam and the confining solenoid should be developed.

The committee felt that the best approach would be to start with a well defined experiment that could consist of a single electron lens designed in such a way that it would only minimally perturb the Booster lattice. This would most likely require that the beta functions at the electron lens would have to remain unequal. The focussing and coupling effect of the solenoid should be compensated as well as possible. It is expected that a single lens would not result in substantial improvements to the Booster performance, if any, but the effect of the electron lens on the Booster beam properties could be studied. Of course, this will require that simulation studies of the Booster with a single lens were completed to which the observed beam effects can be compared. If the effect of a single lens on a high intensity proton beam is well understood one could then proceed to the design and construction of the full system consisting of three electron lenses.